INTELLIGENT TRANSPORTATION SYSTEMS STRATEGIC DEPLOYMENT PLAN

Functional Area Plan

prepared for

Nevada Department of Transportation Regional Transportation Commission of Clark County, NV

by

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1. Introduction

1.1 Overview

This report presents a functional area plan. It specifically examines five areas of Intelligent Transponation Systems (ITS) functionality. These areas of surveillance, communications, traveler interfaces. control strategies, and data processing are evaluated in context of ITS user services relevant to a Las Vegas Valley core infrastructure in context of proposed system configurations.

1.2 Las Vegas Core infrastructure

The User Service Plan for the Las Vegas Valley documented a concept of core infrastructure. Core infrastructure as discussed by US DOT leverages existing infrastructure and strengthens existing institutional ties. It is expected to be a public sector push in the near term fostering private sector development.

Core infrastructure is comprised of the following five ITS service areas:

- Regional Multimodal Traveler Information Systems,
- Traffic Signal Control System(s),
- Freeway Management System.
- Transit Management System, and
- Incident LManagement Program.

Table 1. presents a mapping of core infrastructure service areas to ITS user services and the stants of the core infrastructure service area in the Las Vegas Valley.

Table 1. 0 Core Infrastructure in the Las Vegas Valley.

Core Infrastructure Service Area	Las Vegas Valley Status	ITS User Service(s)
Regional Multimodal Traveler Information Systems (RMTIS)	Does not currently exist. Could be a single center or wide-area network of facilities. Needs to be developed compatible with national architecture	En-Route Driver Information
		Route Guidance
		Pre-trip Travel Information
		En-route Transit Information
Traffic Signal Control System(s)	Upgrade of LVACTS underway. Need to link to future freeway operation and to RMTIS.	Traffic Control
Freeway Management System	None exists. Needs to be linked to traffic signal systems, incident management, and RMTIS	Traffic Control
Transit Management System	Currently CAT bus and paratransit systems. Conceivably could be one system tied to RMTIS.	Public Transportation Management
		Demand Management & Operations
		Personalized Public Transit
		Ride-matching & Reservation

Core Infrastructure Service Area	Las Vegas Valley Status	ITS User Service(s)
Incident Management Program	Part of LVACTS upgrade. Needs inter-jurisdicitonal agreements.	Incident Management

2. Functions Applicable to the User Services in the Core Infrastructure

The Federal Highway Administration (FHWA) categorizes ITS functionalities into seven areas in the *National Program Plan.* These seven areas are:

- Surveillance.
- Traveler Interface,
- Navigation Evidance.
- In-vehicle Sensors,
- Communications.
- Control Strategies, and
- Data Processing.

Similar work in the National Architecture Program captures the functionalities of ITS user services in a logical architecture. This logical architecture analyzes the ITS user services and identifies required inputs, functions, and outputs utilizing a structured analysis approach. By grouping common functions, an integrated system architecture evolves. An architecture that highly leverages existing infrastructure and uses a building block approach for traveler information services provides the structure for Core Infrastructure. Grouping, the architecture functions, and thus the Core Infrastructure. A complete mapping to the FHWA seven functional areas can be made.

The *User Service Plan* documents ITS user services prioritized to satisfy the Las Vegas Valley transponation needs and solve transportation problems through a strategic deployment of ITS technologies. Through this process of identifying and prioritizing ITS user services. functional areas directly applicable to the Las Vegas Valley and consistent with a Core Infrastructure were identified. These five functional areas are:

- Surveillance.
- Traveler Interface,
- Communications.
- Control Strategies, and
- Data Processing

2.1 Description of Functions

2.1.1 Surveillance

Surveillance is defined as the collection of information for traffic, vehicle, weather, ahd hazard conditions. To coIlecr the information, surveillance requires monitoring, processing. and storage of data. Many methodologies exist to perform surveillance incIuding location specific lane(s) detection, reports from travelers and police, and aggregated vehicle probe information or roadway network monitoring.

Traffic Surveillance monitors streams of traffic data. and processes and stores the data bused upon collection requirements. This collection can be performed on traffic at specific detection locations or on an area wide level. Technologies to perform traffic surveillance include inductive loops. infrared. radar. microwave, machine-vision. acoustic. and video imaging. Traffic surveillance is the foundation for virtually all aspects of ITS user services and especially for Core Infrastructure. As the major input for most derived traffic and traveler information. both local specific information as well as network level information are critical to any ITS operation.

Vehicle Surveillance monitors specific vehicles. and processes and stores data based upon collection requirements. This collection is typically location specific. Vehicle surveillance is generally an integral component of Automatic Vehicle Identification/Location (AVI/AVL) and Automatic Vehicle Classification (AVC) involving technologies utilized for location specific traffic surveillance. Without any deployment to validate vehicle surveillance as a surrogate for traffic surveillance, vehicle surveillance remains specific to Commercial Vehicle Operations (CVO) and Electronic Toll Collection (ETC) applications. While most open architectures support the usage of vehicle surveillance for derived traffic and traveler information, cost and jurisdiction implications have made its implementation very localized.

Weather Surveillance monitors the environment, and processes and stores data based upon collection requirements. This collection includes the temperature. barometric pressure, precipitation. wind. and visibility. Weather surveillance is a critical albeit overlooked aspect of ITS. With the plethora of information that ITS offers, weather parameters will factor into transportation decisions both directly and indirectly.

Hazard Suveillance monitors hazardous conditions. and processes and stores data based upon collection requirements. This collection includes road condition hazards such as snow. flood. and rocks as well as hazardous materials especially for tunnels. Technologies to sense toxic and radioactive materials are utilized including video imaging and other sensors. Hazard surveillance is an area that provides immediate benefits co traditional transportation management with respect to minimizing potentiai hazardous situations and micigatins the risks due to their occurrences.

2.1.2 Traveler Interface

Traveler Interface is defined as the process by which a traveler asks and receivers information inside and outside the vehicle. The interface is dependent upon the communications medium with respect to broadcast or interactive functionalities.

Out-of-Vehicle Traveler Interface provides a connection for the traveler when not in a vehicle. This interface can be pre-trip such as at a home or work, at other fixed locations such as bus/train/sea/air or terminals, shopping or business centers, airports, or street-side. or mobile, but non-vehicle specific. Technologies include computers, interactive and broadcast television. radio. kiosks. and personal digital assistants. The out-of-vehicle traveler interface includes both wireline and wireless communications. ITS utilizes and thus leverages the existing and evolving systems for the out-of-vehicle travelers including advanced interactive cable television systems and the information highway. Where applicable the utilization of existing interfaces will provide easier and consistent access to traffic and traveler information. Early emphasis on the interface might provide misleading results as implied by the building block structure of core infrastructure where sufficient timely information might be the single most critical factor for traveler information services Success.

In-Vehicle Traveler Interface provides a connection for the traveler inside the vehicle. This interface is for the en-route traveler in the vehicle and includes devices attached to or utilized in the vehicle and devices outside the vehicle but targeted to the in-vehicle traveler. Technologies include car radios. cellular telephones, and Changeable Message Signs (CMS). In-vehicle interfaces are not just limited to traveler information and must address human factors issues as well as vehicle architectural issues. These interfaces are involved with nearly all aspects of ITS as it pertains the driving public and even to the transit ridership with user services that address multimedia information access and transmission co transit patrons.

3.1.3 Communications

Communication is defined as the transmission of information between transportation infrastructure, vehicles, and travelers. Communication is the interconnection between all ITS functions that carry the input and output of data.

1-Way Mobile Communications provides an interconnection from infrastructure elements either at central facilities or at distributed roadside locations to the mobile vehicles. This broadcast of information utilizes various communications technoIogies including radio such as Highway =AdvisoryRadio (HAR) encompassing conventional AM/FM radios and digital radio. short-range RF and IR vehicle to roadside communications, and microwave. As addressed in the National Architecture. an incremental capability of user services is a critical principle for ultimate deployment success and finds implementation through broadcast. Broadcast of usable and good information provides a mean to address equity issues as well.

2-Way Mobile Communications provides an interconnection between infrastructure elements either at central facilities or at distributed roadside locations and the mobile vehicles. This interactive information exchange utilizes various communications technologies such as cell-based mobile phone systems including cellular, CDPD, ESMR, and CDM. and satellite systems. Interactive communication is a critical characteristic of long-term ITS user services as well as a means to satisfy initial first user benefits such as systems similar co the TravTek FOT.

Stationary Communications provides an interconnection between infrastructure elements either at central facilities or at distributed locations and the travelers. This interactive information exchange utilizes the existing public telephone system, cable television, Integrated Services Digital Network (ISDN), fiber optic networks, and ocher wireline communication networks. Although some major telecommunications Firms may have Ions term objectives subscribing to the Negroponte switch, where wireline and wireless applications reverse their communications medium such as all telephone migrating to wireless and all television migrating to wireline, transportation is investing heavily in wireline especially in the transmission of video data and network connections between centers within a metropolitan area.

2.1.1 Control Strategies

Control Strategies are defined as traffic flow control mechanizations to include signalization and restriction. Methodologies to perform control strategies include permutations of surface street. arterial roads. and highways.

Signalized Control Strategies provide various signalized traffic controls from time-of-day to real-time adaptive and includes such strategies such as ramp metering on highways and reversible lane management. Specific to traffic management user services, but foundation for core infrastructure, advanced signalized control strategies are critical elements of nearly all strategic deployment plans.

Restrictive Control Strategies provide operational ,methods to restrict roadway usage including High Occupancy Vehicle (HOV) lanes, parking restrictions and congestion pricing. Mostly tied to demand management, restrictive control strategies with the exception of HOV lanes are still treated as last resort. With increased surveillance resulting in more available information, most initial plans estimate high traveler benefits without the usage of restrictive strategies.

2.1.5 Data Processing

Data Processing is defined G the processing of traffic and travel information for traffic prediction. traffic control, and databases,

Traffic Prediction Data Processing provides real-time prediction and traffic assignment. Traffic prediction data processing for arterial applications have been successful: however, network level optimization remains technologically and especially jurisdictionally challenging.

Traffic Control Data Processing provides real-time control of traffic. Directly associated with traffic management user services, traffic control data processing faces technological hurdles for real-time applications still unproven in actual deployments.

Database Data Processing provides manipulation of transportation data into usable information input or output. Addressed by nearly all ITS user services and appropriately represented in the National Architecture by an abundance of data stores, the importance of database data processing for timely and accurate information is utmost. Advanced applications such as data fusion and real-time infrastructure supported fleet management and route guidance provide paths for technological advancement of transportation related database data processing.

3. Functional Areas Needed for other ITS User Services

Core infrastructure presents a building block approach to ITS that will enable additional ITS user services. For the Las Vegas Valley core infrastructure. nine user services functionalities are specifically addressed. As with the approach to utilize maximum leverage of existing infrastructure and existing jurisdictional relationships, it is important to understand the functionality Las Vegas Valley core infrastructure provides for additional user services.

The ITS user services are individually incremental. i.e., short-, medium-, and long-term functionalities are addressed in each user service. Capabilities provided through implementation of one user service are not prerequisite for the implementation of another user service. Although this facilities a "shopping list" approach allowing local preferences to drive the shopping process, common functionalities provided by multiple user services are not specifically addressed. The National Architecture Program solved this overlap utilizing the Market Packages concept.

The National Architecture Program uses Market Packages to implement user services. Market Packages are similar to core infrastructure with respect to incremental capabilities. Inherently incremental, Market Packages aggregate the allocation of functionalities to physical components addressin(J the who builds, who maintains, and who buys questions. For example, it is understood that many traveler information services will not be available until traffic management services are in place. Thus, incrementally certain elements of traffic management must be in place before related elements of traveler information is deployed as is the case for traffic surveillance collection for traffic congestion information dissemination. As illustrated in the previous example. it is not only a question of what additional functional areas are required for additional user senices, but what additional functionalities are required for additional user services.

3.1 Prioritized ITS User Services for Las Vegas Valley

The list of ITS user services in the *User Services Plan* is provided in ranked priority for the Las Vegas Valley:

1. Traffic Control.
2. En-Route Driver Information,
3. En-Route Transit Information,
4. Incident Management.
5. Route Guidance,
6. Pre-Trip Travel Information,
7. Public Transportation bfanagement,
8. Personalized Public Transit,
9. Traveler Services Information.
10. Emissions Testing and &litigation,
11. Demand Management and Operation,
12. Ride-matching and Reservation,

13. EmergencyVehicle Management.
14. Public Travel Security.
15. Hazardous Materials Incident Response,
16. Electronic Payment Services.
17. Railroad Crossins Safety.
18. Commercial Vehicle Electronic Clearance,
19. Commercial Vehicle Administrative Processes,
20. Commercial Fleet Management.
21. Safety Readiness.
22. Intersection Collision Avoidance.
23. Automated Highway System.
24. Pre-crash Restraint Deployment.
25. Emergency Notification & Personal Security,
26. Vision Enhancement for Crash Avoidance,
27. Automated Roadside Safety Inspection.
28. On-Board Safety Monitoring,
29. Longitudinal Collision Avoidance. and
30. Lateral Collision Avoidance.

The Laj Vegas Valley core infrastructure includes the first nine user services. Thus, following is a cursory analysis of functional needs of the remaining 21 user services given the first nine are implemented.

3.1.1 Traffic Management User Services

The following is a list of non-Las Vegas Valley core infrastructure user services related to traffic management:

- Emissions Testing and Mitigation
- Demand Management and Operation, and
- Railroad Crossing Safety.

The user services of Traffic Control and Incident Management are to be deployed as part of the Las Vegas Valley core infrastructure. Much of the communications infrastructure would be leveraged for the Emissions Testing and Mitigation and Railroad Crossing Safety user services. Specific surveillance requirements will be different; however. the interconnections should receive much synergy. Data processing requirements will differ and would require separate operations. It is not anticipated that these three user services would impact other user services and it appears appropriate that they remain non-core infrastructure.

3.12 Traveler Information User Services

The following is a list of non-Las Vegas Valley core infrastnxture user services related to traveler information:

- Electronic Payment Sekces.

It is arguable that Electronic Payment Services exist as parts of other traveler information user services. For the more mainstream application for Electronic Toll Collection (ETC), this user service. although an element of the FHWA core infrastructure, is not critical to the Las Vegas Valley. The requirements for ETC will be substantial with respect to short range Vehicle to Roadside Communication (VRC). Infrastructure to manage the ETC data will be required as well the implementation of ETC specific surveillance equipment. .\s this technology is neither untested nor risky, it is anticipated that any future need for ETC will be readily solved.

3.1.3 Transit Management User Services

The following is a list of non-Las Vegas Valley core infrastructure user services related to transit management:

- Ride-matching and Reservation, and
- Public Travel Security.

Ride-matching and Reservation is certainly an extension of the core transit user services and will be benefit from the infrastructure and data processing to be deployed. The performance and information security requirements for dynamic ride-matching will leverage data base processing efforts from the core transit user services. Public Travel Security will require much more surveillance requirements especially with respect to video with potentiaIly high communications impacts.

3.1.4 Commercial Vehicle Operations (CVO) User Services

The foIlowing is a list of non-Las Vegas Valley core infrastructure user services related to commercial vehicle operations:

- Hazardous Materials Incident Response,
- Commercial Vehicle Electronic Clearance,
- Commercial Vehicle Administrative Processes,
- Commercial Fleet Management,
- Automated Roadside Safety Inspection, and
- On-Board Safety Monitoring,

The Hazardous Materials Incident Response user services requires an interconnection with Traffic Management and Emergency services. These interconnections are expected to be at the facility level utilizing existing wireline communications and are not expected to benefit greatly from core user services. The roadside elements of CVO will require much surveillance, VRC, and an extensive infrastructure investment. As CVO is not expected to impact the Las Vegas Valley ITS efforts, it is indeed appropriate that these user services are deIayed for deployment. While the functional requirements are substantial. a loss of joint deployment benefits with core infrastructure elements does not seem to exist as the functional requirements are quite unique to CVO.

3.1.5 Emergency Management User Services

The following is a list of non-Las Vegas Valley core infrastructure user services related to emergency management:

- Emergency Vehicle Management, and
- Emergency Notification & Personal Security.

Emergency Vehicle Management requires vehicle sensors, facility processing, and an interconnection between vehicles and facilities. In addition, Emergency Notification & Personal Security requires vehicle sensors and facility processing. With the exception of ties with Incident Management. Emergency Management is virtually independent of the core infrastructure user services.

3.1.6 Advanced Vehicle Control and Safety User Services

The following is a list of non-Las Vegas Valley core infrastructure user services related to advanced vehicle control and safety:

- Safety Readiness.
- Intersection Collision Avoidance,
- Automated Highway System,
- Pre-crash Restraint Deployment.
- Vision Enhancement for Crash Avoidance,
- Longitudinal Collision Avoidance, and
- Lateral Collision Avoidance.

Cost of the Sensor interfaces. and processing requirements of these user services are isolated to the vehicle with the exception of Intersection Collision Avoidance, Automated Highway System (AHS). and potentially Lateral Collision Avoidance. Transit and commercial vehicle application of Transit Management and CVO require examination for on-vehicle sensor and processing requirements in light of expected vehicle control and safety systems. Proposed vehicle databus architectures require examination but mostly at the vehicle manufacturer level. System level impacts such as interconnection requirements between vehicles and infrastructure for intersections and AHS are expected to leverage traffic management functionahty deployed with core infrastructure user services.

4. General Requirements of the Functions

The five functional areas of ITS are integral elements of all user services. Nine user services haie been identified as critical for the strategic deployment of ITS in the Las Vegas Valley. These nine user services are:

- En-Route Drive Information,
- En-Route Transit Information,
- Traffic Control.
- Incident Management.
- Route Guidance,
- Pre-Trip Travel Information,
- Public Transportation Management,
- Personalized Public Transit, and
- Traveler Services Information

4.1 Surveillance

Surveillance is an integral element of the Incident Management user service. Incident management includes distributed location specific surveillance along with reports that provide traveler accounts of incident and environmental considerations such as weather and Harvard that is generally collected at a central facility. In the Las Vegas Valley, the LVACTS and Airport Authority are the primary agencies that perform this function.

Transit management for both Public Transportation Management and Personalized Public Transit user services as well as for transit related information of the En-Route Transit Information user service require surveillance functionalities. This collection and dissemination from surveillance information by the RTC is consistent with current asency responsibilities. Surveillance to monitor transit schedule adherence and static applications such as fare and schedules are input to transit data processing strategies.

The Route Guidance user service includes surveillance for optimal performance. In addition, Pre-Trip Travel Information and En-Route Driver Information user services utilizes surveillance information. FHWA Core Infrastructure deployment would anticipate a public agency to manage the traveler information until private sector involvement increased to privatize the operation. Whether the traveIer information is publicly or privately operated, surveillance from all agencies and entities must be leveraged for maximum benefit.

4.2 Traveler Interface

Transit related user services require both in-vehicle and out-of-vehicle traveler interfaces. RTC would provide fixed location and mobile interfaces for inquiries and dissemination of transit information.

Traveler information user sekces will require both in-vehicle and out-of-vehicle traveler interfaces for information inquiries and dissemination. As previously discussed, it is anticipated that the initial traveler information agency will be a public agency. possibly an outgrow th of LVACTS

4.3 Communications

All user services require communications. The traffic management user services are highly dependent upon reliable stationary communications for the transporting of surveillance information and effective implementation of traffic control and incident management strategies.

The transit related user services require effective mobile communications to locate transit vehicles and communicate information between the RTC and the transit vehicles. Stationary and mobile communications are critical to the accurate and timely delivery of transit information to transit users.

The traveler information user services are centered upon receiving inquiries and dissemination traveler information across all communications medium.

4.4 Control Strategies

The Traffic Control user service is the only user service affected by this function. LVACTS shall implement centralized and distributed signalized and restrictive control strategies for various system configurations for optimal traffic control including surface streets, arterials, and freeways.

4.5 Data Processing

As wirh the communications functionality, data processing is critical to all the user services. Most data processing will occur in centralized facilities such as RTC for transit, LVACTS for traffic and possibly traveler information.

5.0 Functional Area Evaluation

The functional area evaluation process will recommend system configurations that best support each of the user services. This is done by the development of alternative configurations. mappinÇJ them against ITS functional areas, and trading them off to provide a recommended mechanization. The trade studies consider all relevant factors and provide a well documented indication of all issues considered in the process. These trade studies also provide long-term value by allowing incorporation of future data without requiring repeating of the entire process.

The results are provided both as detailed trade cables, and as summary graphs. It is important co realize that the highest scoring solution often results because its implementation requires little cost. While this makes these recommendations ideal for immediate implementation. lower scoring alternatives may provide great benefit as well, and should be considered as additional funding allows their implementation. This process allows a single trade study to provide short-term, near-term, and long-term solutions.

5.1 Overview of Services and Functions Evaluated

The functional area evaluation focuses on the nine hightest priority user services as determined in the prior task four work. These are:

Traffic control service (includes traffic signal and freeway management)
En-route driver information service
En-route transit information service
Incident management service
Route guidance service
Pre-trip travel information service
Public transportation management service
Personalized public transit service
Traveler services information service

Each of these was then decomposed into several major system configuration items. Each system configuration item is then developed, in concept, into a number of ahemative configurations. The development of these configurations for each of the services is discussed individually later in this section.

Each system configuration has also been evaIuated which of the ITS functional areas it impacts. These are:

Surveillance
Traffic
Vehicle
Weather
Hazard
Traveler information

- Out-of-vehicle
- In-Vehicle

Navigational guidance
- Real-time position
- General guidance

In-vehicle sensors
- Navigation
- Driver safety

Communications
- 1- way mobile
- 2-way mobile
- Stationary

Control strategies
- Signalized
- Restrictive

Data processing
- Traffic prediction
- Traffic control
- Database

The impact on each functional area that is involved in any of the system configurations included in a system configuration item is considered in the trade study for chat system configuration item. These and other factors. along with the weighting of these factors, their evaluation, and the results is also discussed later in this section.

5.2 The Trade Study Process

The detailed process of conducting a trade study for any system configuration can be broken down into a number of steps (Figure 5.2-l). Each of these steps, its usage, and the method by which it is applied. is discussed in the sections that follow.

5.2.1 The Trade Table and its Use

In doing a trade study, a series of trade tables are prepared, one for each configuration to be traded off. A number of these trade cables are included in lacer parts of this section, and any of these can be reviewed during the following discussion.

The trade table is divided into three main sections. The uppermost lists the user service being traded off in this series of tables, names the system configuration, and names and describes the configuration option being evaluated. Below, in the second main section, is a listing of the evaluation factors in the leftmost column. To the right are columns for the assigned weighting. a rating. and their product for each evaluation factor. The rightmost column is used for comments. The third main area, at the bottom of the cable, holds the total of all products both as a raw total and as a normalized percentage of the maximum. A trade cable using the same factors and weighting is prepared for each alternative configuration.

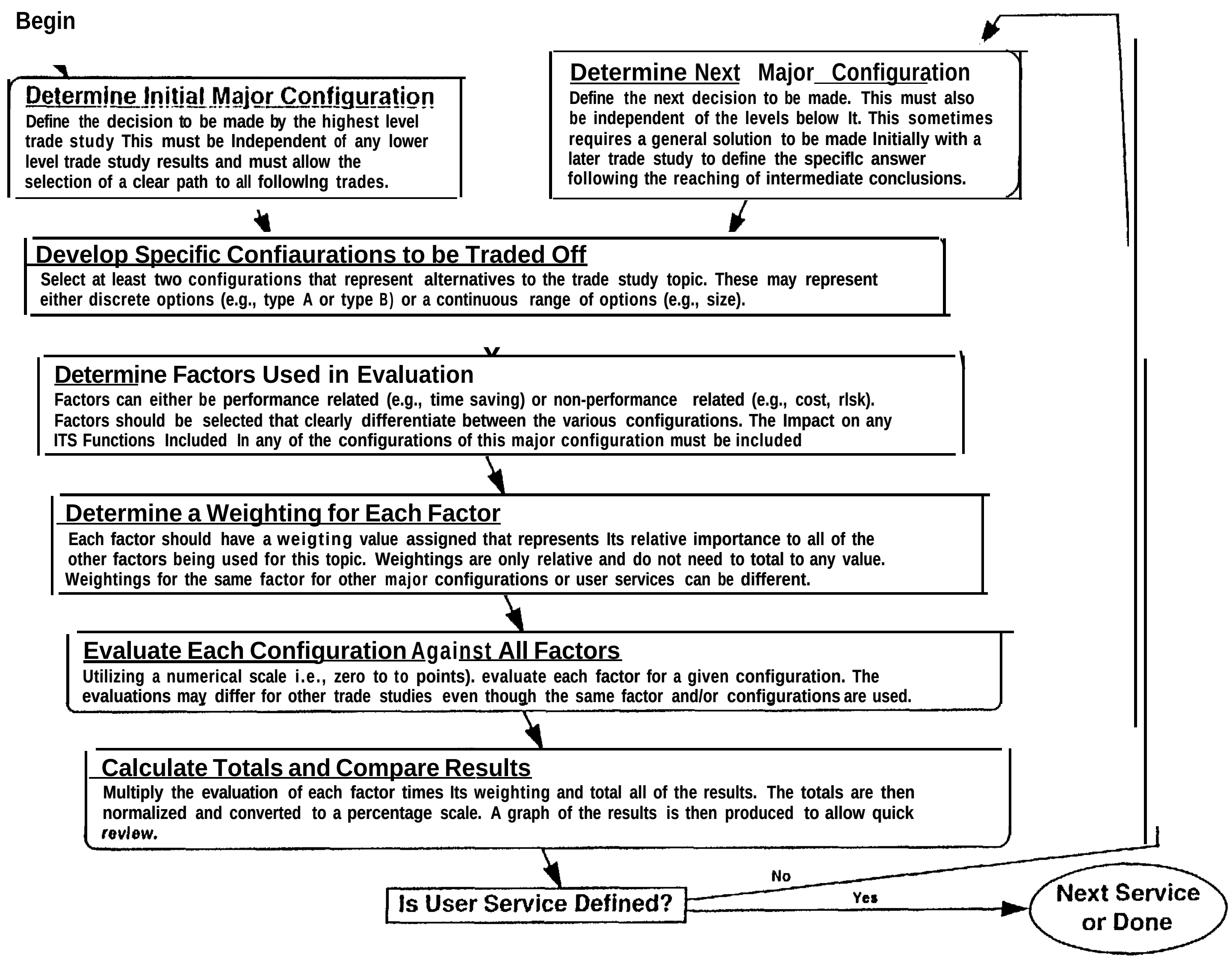

Figure 5.2-1 The Trade Study Process

Trade studies for other sbsrcm configurations. or confipuration options. use the same process but do not have to use the same factors. Even where the same factor is used, the weighring may differ where a different part of the system is being studied.

One important point to note is that later trade studies may use inputs that are dependent on decisions reached in other trade studies. To resolve this problem, it is necessary to prioritize the order in which the trades are done. This allows initial decisions to be used in later trade studies.

5.2.2 System Configurations

For any given type of user service. certain basic actions or activities are required. In analyzing these, a clear definition of what is required to provide a user service can be developed. In their most basic form, a system configuration item is the simplest item by which one action in support of a user service can be separated from another action required for some other part of the same service. For the requirements of this trade study process it is necessary to decompose a user service into the several major system configuration items that make it up.

When besinning a trade study, it becomes apparent that almost everything associated with a given user service could be defined as a system configuration item. Separation of these system configuration items into those which were to be found during the trade study process (dependent variables). those which may be useful as an input to the trade study (independent variables). and those that are redundant or otherwise not useful is required. Selection is done by deciding which would give the most useful results for the trade study at the level of overall functional determination. These are assessed based on industry standard configurations available equipment often utilized configrations. or similar factors.

Having defined the system configuration items. it is necessary to review them and to test their use in actual trade tables. This discloses which are at too high a level and which need to be further subdivided to allow finer resolution, or which may be combined. From this process the exact listing of which are to be traded off is developed. Because the goal of this task five effort is to consider top level requirements, many lower level options are not included here but will be utilized in the next task to derive a detailed system architecrurs.

3.2.3 Determination of Configuration Options

Once a system configuration item has been defined and evaluated as usable, it is necessary to develop an idea of the range of configurations or values that it may assume. To better understand this process it is first necessary to realize that system configuration options can be divided into two basic types. The first of these are the only type utilized during this high level trade study process. These describe only discrete or alternative sets of conditions. Through the application of knowledge of typical systems and best engineering judgment it is possible to define a number of these cases. At this point, the testing of the configuration options in the trade study process is ssain necessary to confirm the usabIlity of the types chosen.

A second type of configuration option are those that have a continuous ranse of values. These can be evaluated to determine an optimum value, such as size or speed, to be utilized. At the level of the trade studies provided in this report none of this type were utilized.

5.2.3 Evaluation Factors

During the development of the configurations to be traded it is necessary to select those that are dependent on various inputs. These inputs are largely the independent variables that resulted from this same analysis. Because they drive the evaluation process, they are caIled evaluation factors.

In reviewing typica evaluation factors, it is found chat it is possible to divide them into two basic types. This is done by judging their relationship with the desirability of a given system configuration. Those that typically result in better system performance are termed "performance factors". Those factors that. while they may or may not have an impact on performance result from other limitins constraints (e.g.. cost) are termed "non-performance" factors.

One critical point to understand is the effect of each of these types of evaluation factors on the overall trade study process. In almost every case it is found that all performance factors tend to drive the trade study process to one boundary configuration. The non-performance factors typically drive the process in the opposite direction. Only by the inclusion of both sets of factors can a trade be conducted that yields a reasonable compromise betwee n both types of inputs.

5.2.3.1 Performance Factors

Specific performance factors were developed that accurately reflect the goals of this project. Those factors that could be developed within the data base available to this project were selected for inclusion.

5.3.3.2 Non-performance Factors

All ITS functions rhat are a part of a given system configuration item are *included as non-performance factors. This is done to allow an assessment chat the proposed configuration will have on them. A function is included if any of the configuration options listed under the system configuration being evaluated lists that function. Also included as non-performance factors is such items as cost. risk, and ease of integration with existing systems. These factors operate directly against the performance factors to balance the overall trade study.

5.2.4 Weighting

For a particular trade study, each evaluation factor has assigned to it a relative weight. These weights are an indication of the relative importance of one factor to all other factors. The key uord to understanding this process is relative. In the assignment of their weights no attempt is made to have them come out to a particular total or add up to a fixed percentage. All weights are simply assigned by judging each factor against all of the other factors being used.

Within a particular trade study, the weight of a particular evaluation factor is held constant. For other trade studies that may use a factor of the same name the weight can be different.

5.2.3 Rating

In order to calculate a numerical result for the trade study process a rating must be assigned for each evaluation factor based on the relative merit that a given configuration provides. The most common scale, and the one used here, is a one to ten point rating, with 10 being best. Assignment of more detailed values beyond a ten point scale has been found to seldom provide improved results.

When these specific ratings are developed for each evaluation factor in a given configuration they are listed in the trade table. When the ratings are assigned in a correct, relative order to each other. the relationship between them provides a relative indication of value and does not always maintain a Linear relationship with calculated performance values.

5.2.5.1 Performance Factors

In the case of performance factors, a value is developed that increases as they provide a performance improvement (e.g.. faster response) or increased desirability (e.g.. improved safety). The development of this value is possible by mathematical, graphical. historical data. industry standards. or other clearly defined processes.

5.2.5.2 Non-performance Factors

For non-performance factors. a vaIue is developed that decreases as the configuration has a greater impact on this factor.

5.2.6 Calculation of Product

The product is simply the weight times the rating, It is found for each factor, both performance and non-performance. and for each configuration option. This product reflects both the weight and the relative rating.

5.2.7 Total Product

When all of the products for a given configuration are found, they are totaled. This total is given in the trade table as the total product. It is important to note that these totals allow comparison of one configuration to another only within one specific trade study.

5.2.8 Normalized Product

To allow a more srraightforward comparison of products. one that shows relative differences between the varying configurations directly, a method of normalizing them was developed. These result in the normalized total. The normalization process is carried out as follows. The total of all of the weighting numbers is found. The maximum obtainable rating is equal to the sum of the highest possible rating for each factor (10) times its weight. The normalized product is then equal to the total product divided by the maximum possible rating times 100 percent. As in the case of the total product, it is important to not compare the normalized product from one trade study to that of another trade study.

5.2.9 Formation of Conclusions

Within each trade study the most desirable choice is the configuration having the highest normalized product. However, some judgment must be applied if several configurations have similar results. The availability of a certain level of funding may indicate that more than one of the configurations should be implemented.

5.3 Details and Conclusions of the Trade Studies

The following nine sections summarize the trade tables and graphs for each of the user services. Each has been divided into two or more system configuration items. For each of these configurations a number of options have been developed. Each configuration is the subject of a trade study with each option having a trade table of its own.

All of the results are provided as graphs in a format that displays the maximum possibIe range (0 to 100%) across the full width of the graph. In some cases, graphs having an expanded scale are also included to better show fine differences. However. it is important to remember that small differences between options do not indicate a strong preference and that the options should be considered generally equal.

The graphs are then followed by the trade tables. It is strongly recommended that this data be evaluated. including incorporation of “what if " numbers to understand the limitations and permutations of the data. To support this analysis, all trade tables are available in electronic format on request.

5.3.1 Traffic Control Service (includes traffic signal and freeway management)

The providing of traffic control service was decomposed into three configuration items:

Control Strategy
Surveillance Methodology
Analysis Method

The above list is not in the order that would normally be considered, that is, from data coIlection. through processing, to control. During the analysis of this service it was found that the trade study process was better supported by evaluating the control strate requirements first. Thus was due to the fact the control requirements drove the data collection and processing.

5.3.1.1 Control Strategy

Three basic methods of traffic control were considered:

Coordinated Signals
Arterial Route Management
Freeway Controls

Two combinations: coordinated signals plus arterial route management, and one utilizing all three, were also included providing a total of five configuration options.

The resuIts of the trade study indicate that the integration of surface, arterial, and freeway controls is strongly preferable to any other options. Within the three individual options freeway controls were found preferable to arterial, which were preferabIe to surface controls. This is due to the fact that high traffic density increases benefits while limited roadway mileage reduces deployment cost.

5.3.1.2 Surveillance Methodology

Three methods of surveillance were considered:

None (pre-defined or time-of-day)
Manual (visual or field reports)
Automated (loops, vision sensors. etc.)

No combinations were considered here because it is common to utilize each of the lower lever methods as a supplemental or fall-back option in systems using the higher level methods.

The results of the trade study show a preference for automated surveillance. This is preferable over manual systems simply because of the limitations of available staff to continuously monitor a large number of surveillance sites (the large number of sites results from the control strategy of controIling all types of roadways as determined in the previous trade study). While systems using no surveillance are commonly deployed. the are not as effective as automated systems.

5.3.1.3 Analysis Methods

Three methods of analysis were considered:

Dynamic (artificial intelligence plus automatic)
Automatic plus Manual Override
Automatic (algorithm. table lookup)

Combinations were not considered because each of the later options is a superset of those listed below it.

The results of the trade study show a strong preference for the dynamic option System processing that reconfigures itself in response to changing conditions has been shown to provide the most highly optimized response the greatest amount of the time. Also shown is the value of manual tailoring of more traditional automated systems.

5.3.2 En-Route Driver Information Service

The providing of en-route driver information service was decomposed into four configuration items:

Data Processing Strategies
Surveillance Methodology
Navigation Methodology
Dissemination Methods

This order was used in the trade study process because the type of data to be processed influenced the surveillance and dissemination methods. Navigation methods are independent of the other three.

3.3.2.1 Data Processing Strategies

Two data processing strategies were considered:

Static Database
Dynamic Database

The dynamic database is assumed to also have access to all static data.

The results of the trade study show a slight preference to the added capabilities of the dynamic database. In this case it was assumed that a static database would contain historical data as to congestion traffic closures, alternate routes, etc. The dynamic capability adds the real-time data from the surveillance system and increases benefits at the expense of added cost and complexity.

5.3.2.2 Surveillance Methodology

Five methods of surveillance were considered:

Lane Detectors
Video Imaging
Traveler Reports
Police Reports
Roadway Network Monitoring

In order to limit the number of trade studies to a manageable number. the only combination of the first four methods that was considered was the use of all methods as specified in the roadivay network monitoring method.

The results of the trade study require careful interpretation to understand them based on the assumprions used in their generation. The slight preference for traveler reports is based on the fact that there is very little cost in implementing this method. While police reports would seem to be similar the more limited coverage of available field units compared to the wide deployment of vehicles with cellular phones reduces its desirability. For a near-term solution both of these methods provide the fastest way to implement this type of surveillance.

The method that is second by a small margin, lane detectors, is a proven and widely deployed technology. It is the recommended solution where a mid-term or longer plan is required for deployment as funding is available.

The method of video imaging is limited by the large amount of data (images) that must be continuously reviewed in order to provide a reasonable response time.

While a combination of all of these methods (roadway network monitoring) will provide the highest benefits. it is only the fourth most desirable in the trade study results. This is primarily due to the high implementation cost. While this result does not indicate that this is not desirable, it does place it in the long-term category for the support of this user service (note that this only applies to this user service).

5.3.2.3 Navigation Methodology

Five methods of navigation were considered:

GPS
Inertial Navigation
Map Matching
Heading and Distance
Aided GPS

Combinations were not considered. except for aided GPS. because these technologies were considered to be mutually exclusive.

The results of the trade study show that GPS based technologies are preferable. The addition of an aiding option to a basic GPS system provides a marginal benefit during periods of signal loss with IittIe increased cost.

Map matching technology is proven and low cost but sometimes requires resets by the vehicle operator to maintain accuracy. Heading and distance systems are very low cost but withour a map data base cannot provide full driving directions.Inertial navigation systems are still very high cost if useful accuracy is to be provided over an extended travel time.

5.3.2.4 Dissemination Methods

Four methods of dissemination were considered:

Radio
Cellular Telephone
Variable Message Signs
In-Vehicle Displays

Combinations were not considered to limit the number of possible solutions to a manageable number.

The results of the trade study show that transmission of en-route information via existing cellular or paging networks is slightly preferable to similar broadcasts using voice or sub-carriers of commercial stations. While these two options are very similar the wide coverage and lower cost of cellular solutions provides it a slight margin.

The installation of variable message signs can reach the largest number of vehicles at a given point but is limited by the number of signs that can be installed and the overall system cost. While in-vehicle displays may provide the best long-term solution the cost of installing them in all vehicles limits their apphcability at this time.

5.3.3 En-Route Transit Information Service

The providing of en-route transit information service was decomposed into three configuration items:

Data Processing Strategies
Surveillance Methodology
Dissemination Methods

This order was used in the trade study process because the type of data processing influences the surveillance and dissemination methods.

5.3.3.1 Data Processing Strategies

Two data processing strategies were considered:

Static Database
Dynamic Database

The dynamic database is assumed to aIso have access to all static data.

The results of the trade study show a slight preference to the added capabilities of the dynamic database. In this case it was assumed that a static database would contain historical data as to congestion. traffic closures. alternate routes and schedules. etc. The dynamic capability adds the real-time data from the surveillance system and increases benefits at the expense of added cost and complexity.

5.3.3.2 Surveillance Methodology

Five methods of surveillance were considered:

Lane Detectors
Video Imaging
Traveler Reports
Police Reports
Roadway Network Monitoring

In order to limit the number of trade studies to a manageable number, the only combination of the first four methods that was considered was the use of all methods as specified in the roadway network monitoring method.

The results of the trade study require careful interpretation to understand them based on the assumptions used in their generation. The small preference for traveler reports is based on the fact that there is very little cost in implementing this method. For this service "traveler" is assumed to be not only the general public but also other transit vehicles. While police reports would seem to be similar, the fact that police units will cover all parts of the roadway system while traveler reports can concentrate along transit routes reduces its desirability. For a near-term solution both of these methods provide the fastest way to implement this type of surveillance.

The method that is second by a small marsin, lane detectors. is a proven and widely deployed technology. It is the recommended solution where a mid-term or longer plan is required for deployment as funding is available.

The method of video imaging is limited by the large amount of data (images) that must be continuously reviewed in order to provide a reasonable response time.

While a combination of all of these methods (roadway network monitoring) will provide the highest benefits. it is only the third most desirable in the trade study results. This is primarily due to the high implementation cost, limited by the need to focus deployment primarily along transit routes. While this result does not indicate that this is not desirable. it does place it in the long-term category for the support of this user service (note that this only applies to this user service).

5.3.3.3 Dissemination Methods

Four methods of dissemination were considered:

Driver
In-Vehicle Displays

Synthetic Voice
Combination of In-Vehicle Display and Synthetic Voice

Automated display methods were considered to be mutually exclusive of manual announcements by the driver.

The results of the trade study require careful interpretation. The small preference for driver announcements is based on the low cost of this method. This makes it desirable for near-term implementation. It is important to realize that use of the driver may slow down or restrict other driver functions and is not always the most effective way to accurately communicate information to all members of the traveling public.

Both displays and computer generated voice systems provide timely communication of accurate data. The ability of a display to contain graphics and the fact that it is less intrusive on the passengers is the basis for its slight preference over voice. Both methods are limited with in the case of disabled persons (sight impaired for signs, hearing impaired for voice).

The combination of both a sign and voice increases the amount of data of either alone while being less intrusive than a voice only system. This design could be multi-lingual and would best meet the needs of the disabled. These combination systems are optimum for mid to long term deployment.

5.3.4 Incident Management Service

The providing of en-route driver information service was decomposed into three configuration items:

Surveillance Strategies
Data Processing Strategies
Information Reporting

This order was used because the surveillance method effected the data processing requirements.

5.3.3.1 Surveillance Methodology

Five methods of surveillance were considered:

Lane Detectors
Video Imaging
Traveler Reports
Police Reports
Roadway Network Monitoring

In order to limit the number of trade studies to a manageable number. the only combrnation of the first four methods that was considered was the use of all methods as specified in the roadway network monitoring method.

The results of the trade study require careful interpretation to understand them based on the assumptions used in their generation. The preference for traveler reports is based on the fact that there is very little cost in implementing this method. Unfortunately, the nature of incident management limits the reliability of traveler reports. In reporting incidents the an individual public caller is much less likely to be able to accurately proLids all the details required. While the trade study prefers this method, it is recommended only for a very short term solution until other methods can be implemented.

The method that is second. lane detectors. provides reliable indication of the presence of an incident by its effects on traffic flow. This method does require considerable deployment effort but is the recommended mid-term solution.

The combination method included in the trade study, roadway network monitoring is slightly behind lane detectors based on its higher deployment cost. However, due to its added benefits it provides a desirable long-term solution.

Police reporrs are limited in their evaluation by the lesser number of vehicles deployed at any one time as opposed to reports from the general public. While the police can be expected to provide the most accurate reports, they can also be unable to get to an incident due to the congestion that it has caused.

As noted before, the method of video imaging is limited by the large amount of data (images) that must be continuously reviewed in order to provide a reasonable response time. It is Iess desirable until combined with other methods. In incident management video does provide the capability to accurately assess the emergency response required from a remote position.

5.3.4.2 Data Processing Strategies

Three methods of data processing were considered:

Automatic Incident Detection
Prognostic Traffic Control
Data Fusion Technique

The first two are considered mutually independent. The data fusion method includes both of the other methods plus any other applicable methodologies.

The trade study results must be viewed reIative to an implementation time frame. Based on the results of the surveillance trade study. the recommended data processing method to be used is prognostic traffic control. This method relies on previously generated alternative routings and other responses. As the surveillance methods to be provide migrate to provide additional incident data. and more automated data the data fusion technique will become the optimum solution. Since automated incident detection is a subset of data fusion it provides a less complex, but less capable option. Given the rapidly fallins cost of computers, added processing improves capability at minimal cost.

5.3.4.3 Information Reporting

This configuration item was included for completeness but was not the subject of a trade study. This was based on the fact that incident reporting utilizes existing and well developed emergency response systems that are not a part of the ITS deployment.

5.3.5 Route Guidance Service

The providing of en-route driver information service was decomposed into three configuration items:

Data Processing Strategies
Surveillance Methodology
Dissemination Methods

This order was used in the trade study process because the type of data processing influences the surveillance and dissemination methods.

5.3.5.1 Data Processing Strategies

Two data processing strategies were considered:

Static Database
Dynamic Database

The dynamic database is assumed to also have access to all static data.

The results of the trade study show a preference to the added capabilities of the dynamic database. In this case it was assumed that a static database would contain historical data as to congestion, traffic closures, alternate routes and schedules, etc. The dynamic capability adds the real-time data from the surveillance system and increases benefits at the expense of added cost and complexity.

5.3.5.2 Surveillance Methodology

Four methods of surveillance were considered:

Lane Detectors
Video Imaging
Transit Vehicle bfonitoring
Roadway Network Monitoring

In order to limit the number of trade studies to a manageable number. the only combination of the first three methods that was considered was the use of all methods as specified in the roadway network monitoring method.

The results of the trade study indicate that lane detectors providing overall traffic flow information provides the greatest benefit to the route guidance service. The greatly expanded capability of complete road network monitoring is desirable but limited to a second choice by its higher cost. Based on this, these two options are viewed as mid-term and long-term solutions.

As discussed previously. the method of video imaging is limited by the large amount of data (images) that must be continuously reviewed in order to provide a reasonable response time.

A very low cost option the monitoring of existing transit vehicles provides the least desirable solution but could be implemented in the short term.

5.3.5.3 Dissemination Methods

Six methods of dissemination were considered:

In-Vehicle Display
Variable Message Signs
Hand-HeId Device
Synthetic Voice
Kiosk
Telephone

Combinations were not considered to limit the number of trades to a manageable value. Desirable combinations can be inferred from individual results.

Since this user service wouId be provided to persons desiring it, and is not intended for general issues such as congestion mitigation, the ideal dissemination method is an in-vehicle display. Such a display provides maximum information through text, graphics, and multi-lingual capabilities.

With a lower equipment cost (where already present) the use of a telephone is also a desirable solution. Slightly behind the telephone is data communications followed by voice synthesis. Each of these provides less data than a display but could be multi-lingual.

The hand-held device assumed for this trade study would have only general guidance capability (turns, distance) in order to make hand-heId operation possible with limited power sources.

While the kiosk could provide a large amount of information. in many formats, accessibility limits its application to this user service.

The use of variable message signs is a proven technology but is limited by high deployment costs.

5.3.6 Pre-Trip Travel Information Service

The providing of en-route driver information service was decomposed into two configuration items:

Data Processing Strategies
Dissemination Methods

This order was used in the trade study process because the type of data processing influences the dissemination method.

5.3.6.1 Data Processing Strategies

Two methods of data processing were considered:

Static Database
Dynamic Database

The dynamic database is assumed to also have access to all static data.

The results of the trade study show a slight preference to the added capabilities of the dynamic database. In this case it was assumed that a static database would contain historical data as to congestion. traffic closures, alternate routes and schedules. etc. The dynamic capability adds the real-time data from the surveillance system and increases benefits at the expense of added cost and complexity.

5.3.6.2 Dissemination Methods

Five dissemination methods were considered:

Telephone
Fax Back
Radio
Kiosk
Computer

While all of these were close the use of radio was the most desirable due to its wide availability. Much more Iimited access to a kiosk is offset by the capability to provide information more customized to the traveler to make it a second choice. Dissemination through personal computers provides the same high level of information as a kiosk but to a more limited number of peopIe Less interactive but still fully graphic is a fax back system. The use of telephone voice response systems is limited by both capability and public perception.

5.3.7 Public Transportation Management Service

The providing of en-route driver information service was decomposed into three configuration items:

Data CoIlection
Data Processing
Dissemination Techniques

This order was based on the logical flow of information.

5.3.7.1 Data Collection

Three methods of data collection were considered:

Beacons
Navigation Systems
Device Reporz

The device reports is assumed to be all other methods other than the first two. Future work should further define these selections.

The trade study indicates that self-contained navigation systems are somewhat more desirable. This is based on their lack of need for supporting equipment deployed along the transit route and the resulting capability to operate even when diverted to atypical routes. The other methods are also usable with a slight preference to the more proven beacon based technologies.

5.3.7.3 Data Processing

Three methods of data processing were considered:

Static Database
Dynamic Database
Automated Scheduling/Dispatching

Each of the later ones is a superset of those before it.

The trade study indicates a small preference for a highly automated system. Given the rapidly decreasing cost of computers the processing associated with this option is lower in cost than the benefits it provides.

While either of the database options are less desirable, the greater timeliness of a dynamic file makes it preferable to a static database.

5.3.7.3 Dissemination Techniques

Five methods of dissemination were considered:

Kiosk
Telephone
Fax Back
Computer
Cable TV

Various combinations are also possible but were not evaluated to limit the complexity of the trade study.

The trade study found that the telephone was the most desirable choice. Wide availability and the need for only a moderate amount of data is the justification for this recommendation.

The ability to provide graphical data makes the use of a cable TV channel a second choice. SimiIar graphics capability but with fewer people having access to the equipment make the computer and fax third and fourth choices.

While the kiosk has great information presentation capability, the need to travel to it limits its usefulness.

5.3.8 Personalized Public Transit Service

The providing of en-route driver information service was decomposed into two configuration items:

Data Processing Strategy
Dissemination Techniques

This order was based on the logical flow of information.

5.3.8.1 Data Processing Strategy

Three methods of data processing were considered:

Static Database
Dynamic Database
AVL Database

Each of the later options is considered to be a superset of those before it.

The trade study found that a dynamic base would provide the most functionality at an affordable cost. This makes it a desirable short-term solution.

For mid-term or later applrcations the incIusion of an automatic vehicle locating (AVL) system enhances capabilities but at an increased costs.

A static database is the least desirable solution due to only very moderate savings over a dynamic system.

5.3.8.2 Dissemination Techniques

Three methods of dissemination were considered:

Telephone
Fax Back
Kiosk

Various combinations are also possible but were not evaluated to limit the complexity of the trade study.

The trade study found the telephone to be preferable to the others by a considerable margin. Limited amounts of data to be sent make fax (or other graphical systems) of limited increased capability while adding cost or complexity. Because personalized public transit services are often limited in distance, the need to travel to a kiosk is particularly undesirable.

5.3.9 Traveler Services Information Service

The providing of en-route driver information service was decomposed into two configuration items:

Data Processing Strategies
Dissemination Methods

This order was based on the logical flow of information.

5.3.9.1 Data Processing Strategies

Two methods of data processing were considered:

Static Database
Dynamic Database

The dynamic database is assumed to include the capabilities of the static database.

The trade study found the added cost and complexity of a dynamic database were more than offset by its enhanced timeliness.

5.3.9.2 Dissemination Methods

Five methods of dissemination were considered:

Telephone
Computer
Television
Radio
Kiosk

Various combinations are also possible but were not evaluated to limit the complexity of the trade study.

The somewhat larger amount of information to be transferred. combined with the benefits of a highly interactive system make access through a computer the most desirable method resulting from this trade study. This must be evaluated against its limiting effects on persons without computer access and should not be the only method selected.

While more limited in data transfer, its wide availability makes a telephone response system the second choice. Use of television or radio systems are also workable choices and would supplement either of the first two choices.

While the need to visit a kiosk is a limitation. the capabilities it provides makes it a usable. but somewhat less desirable choice.

6.0 Elements to be Included from Existing Systems and Systems Under Construction

Because of the top level analysis performed as a part of this task five report, only limited identification was made of supporting systems. Current projects for synchronized signals and to generate arterial corridors will be included in the lower level trade studies of the task six report.